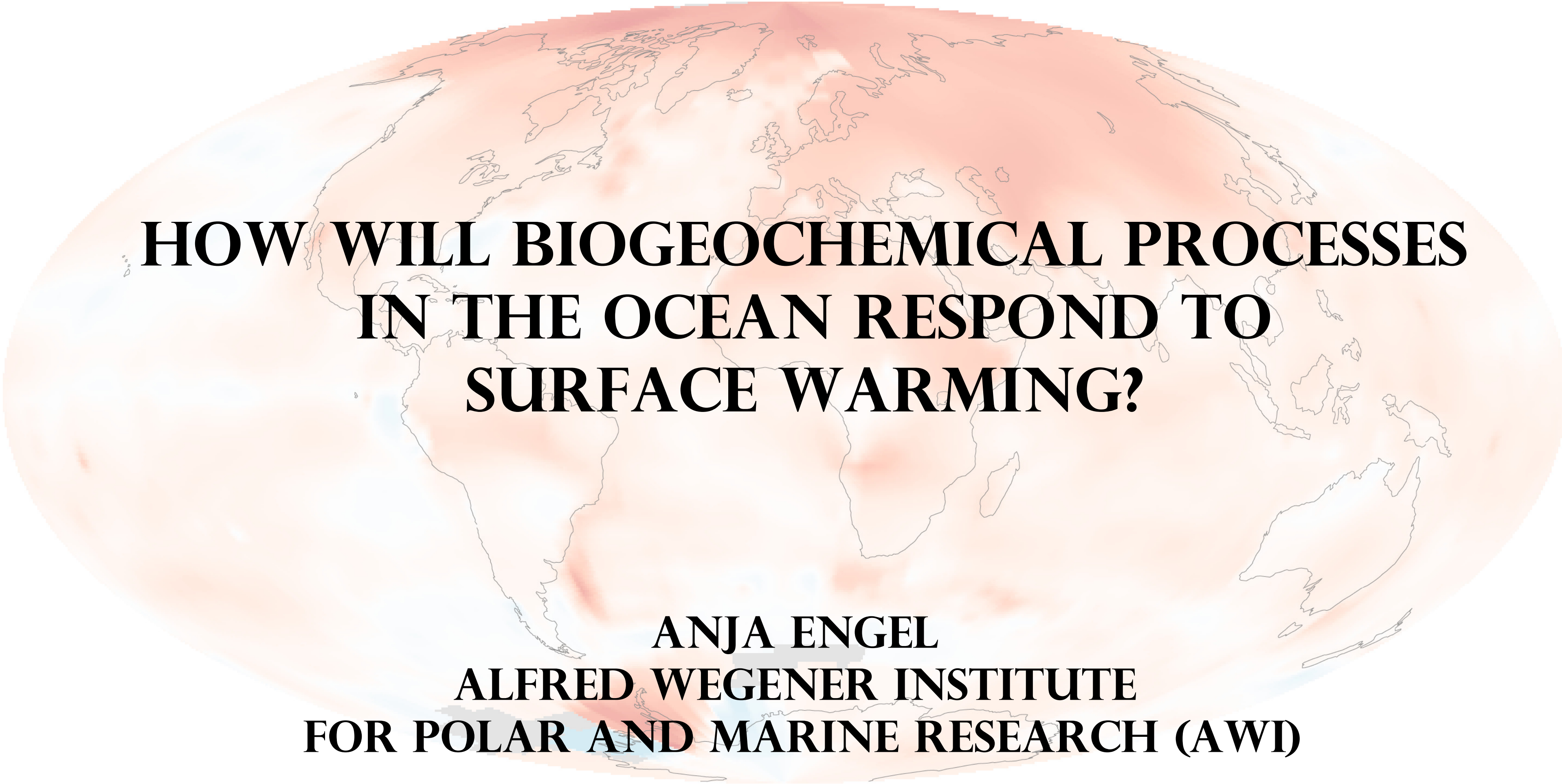
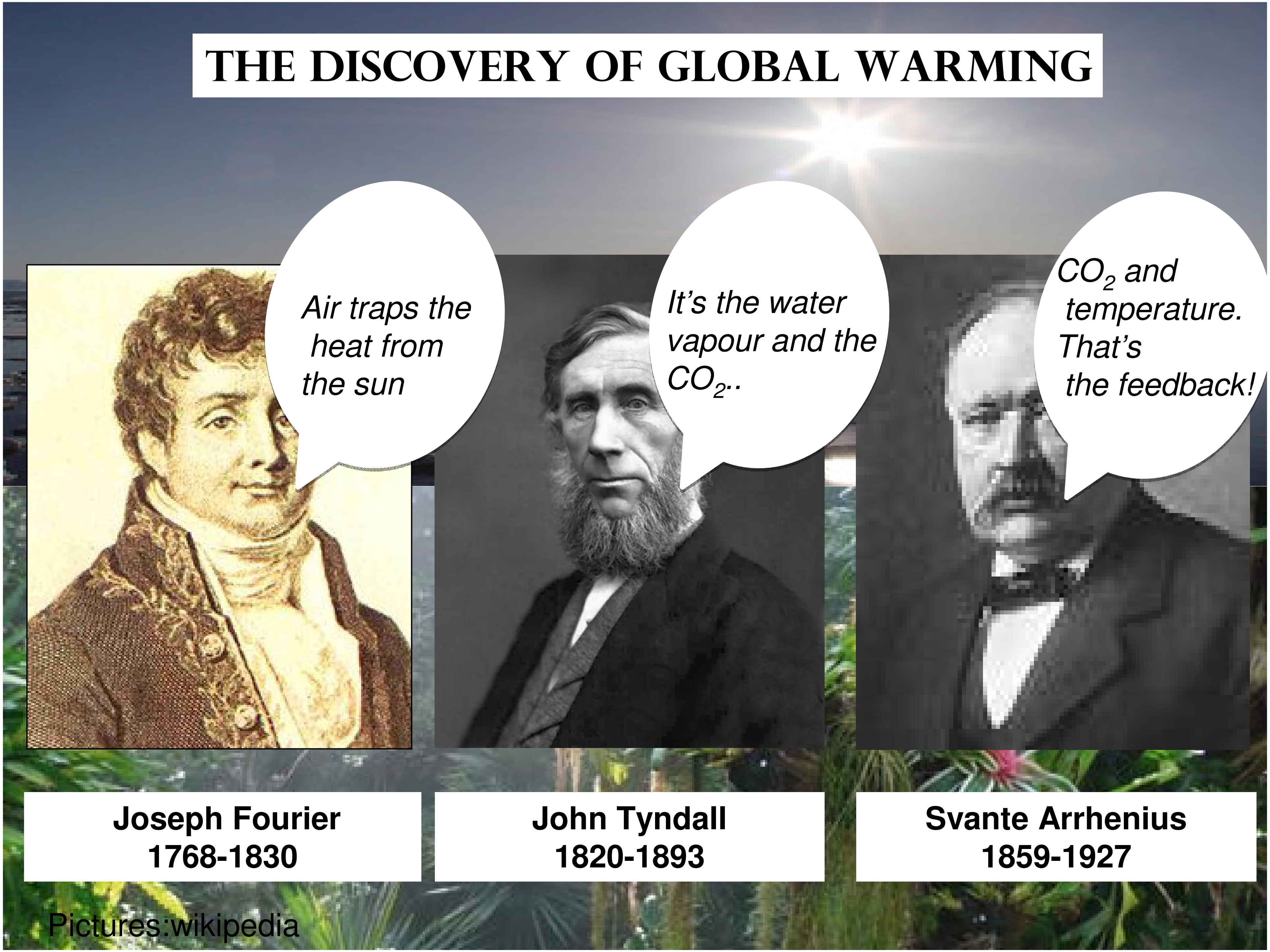
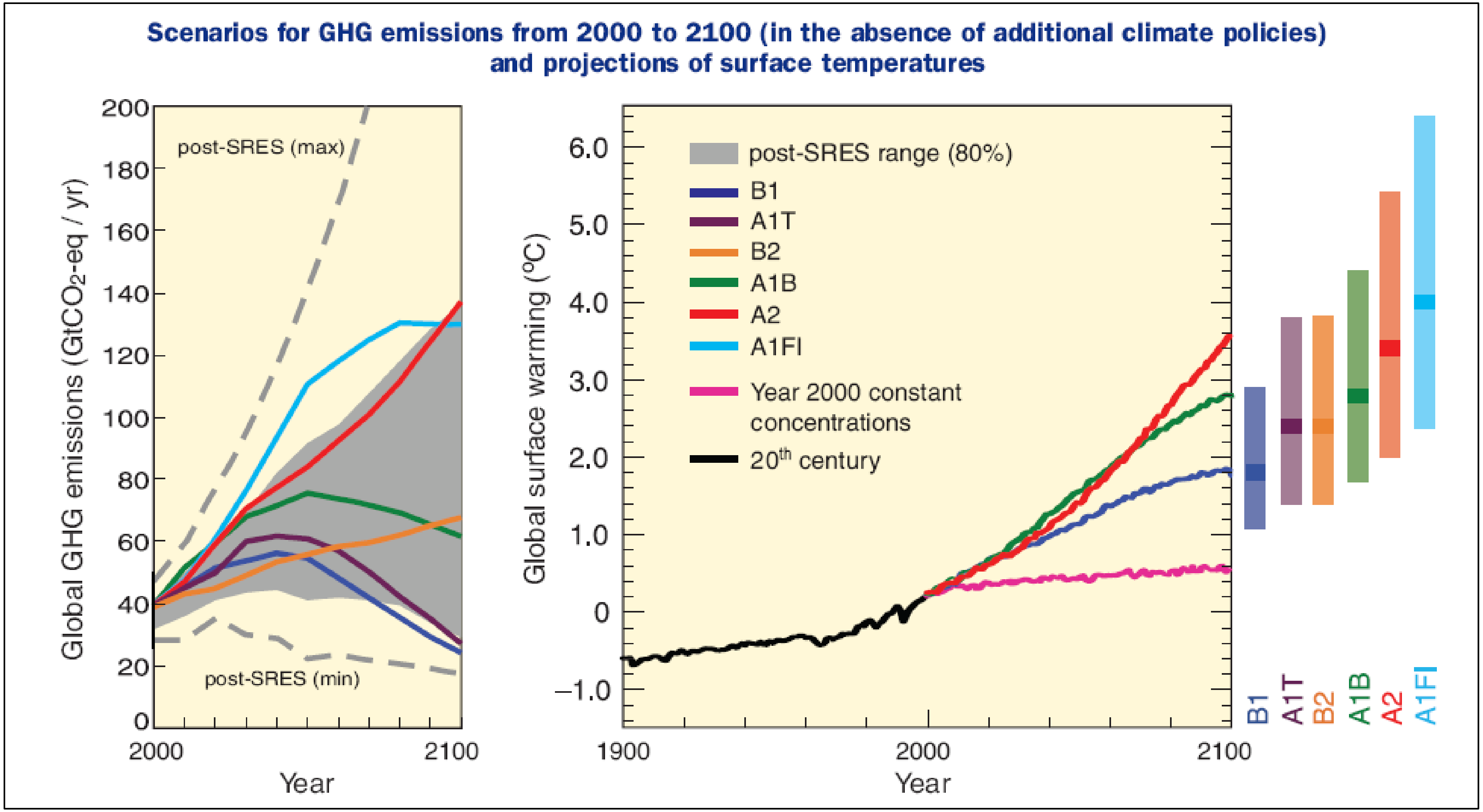


HOW WILL BIOGEOCHEMICAL PROCESSES IN THE OCEAN RESPOND TO SURFACE WARMING?

ANJA ENGEL
ALFRED WEGENER INSTITUTE
FOR POLAR AND MARINE RESEARCH (AWI)

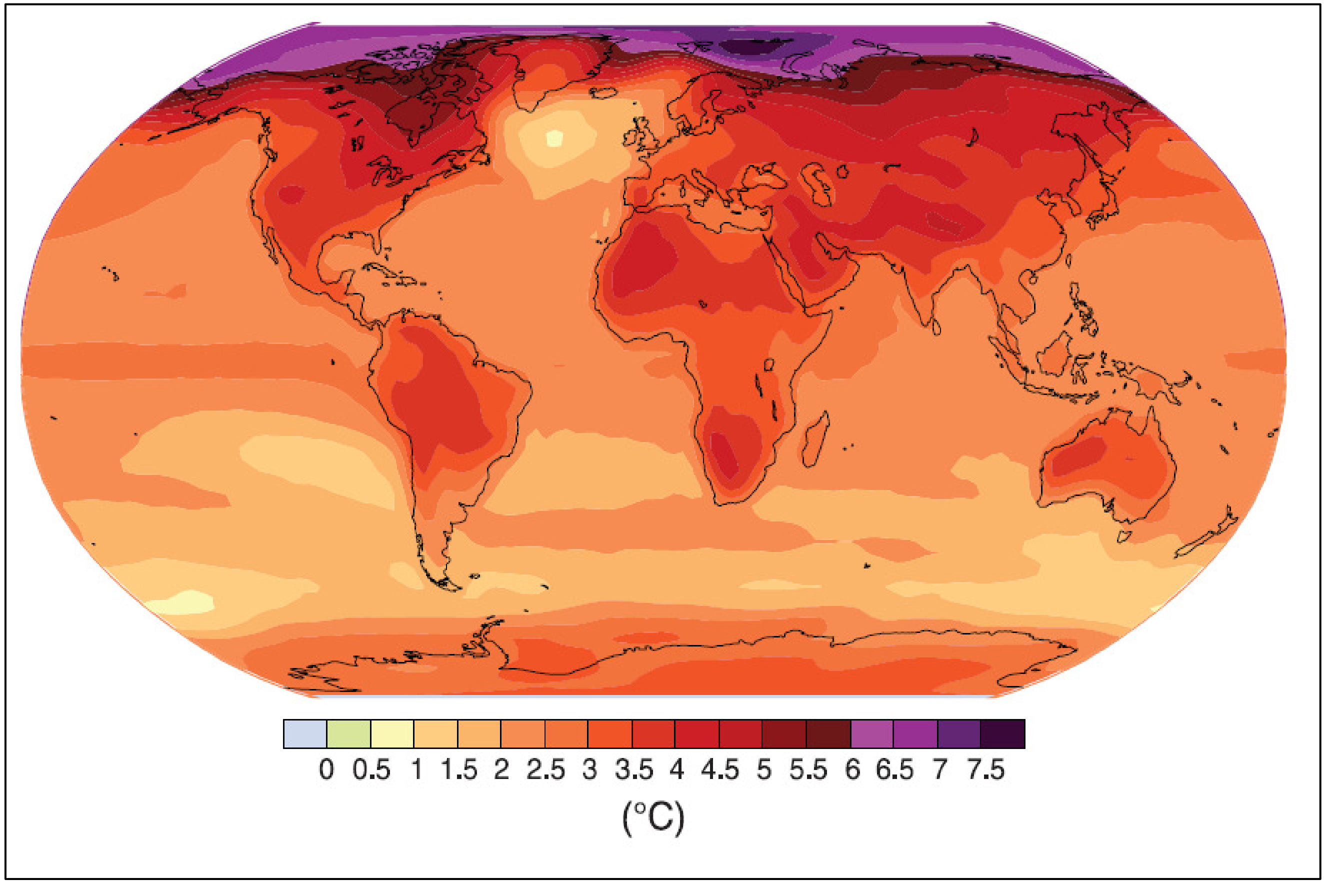

THE DISCOVERY OF GLOBAL WARMING
Air traps the heat from the sun
It's the water vapour and the CO_2..
CO_2 and temperature. That's the feedback!
Joseph Fourier 1768-1830
John Tyndall 1820-1893
Svante Arrhenius 1859-1927
Pictures:wikipedia

FUTURE PROJECTIONS OF GHG EMISSIONS AND GLOBAL MEAN TEMPERATURE



IPCC, synthesis report (2007)

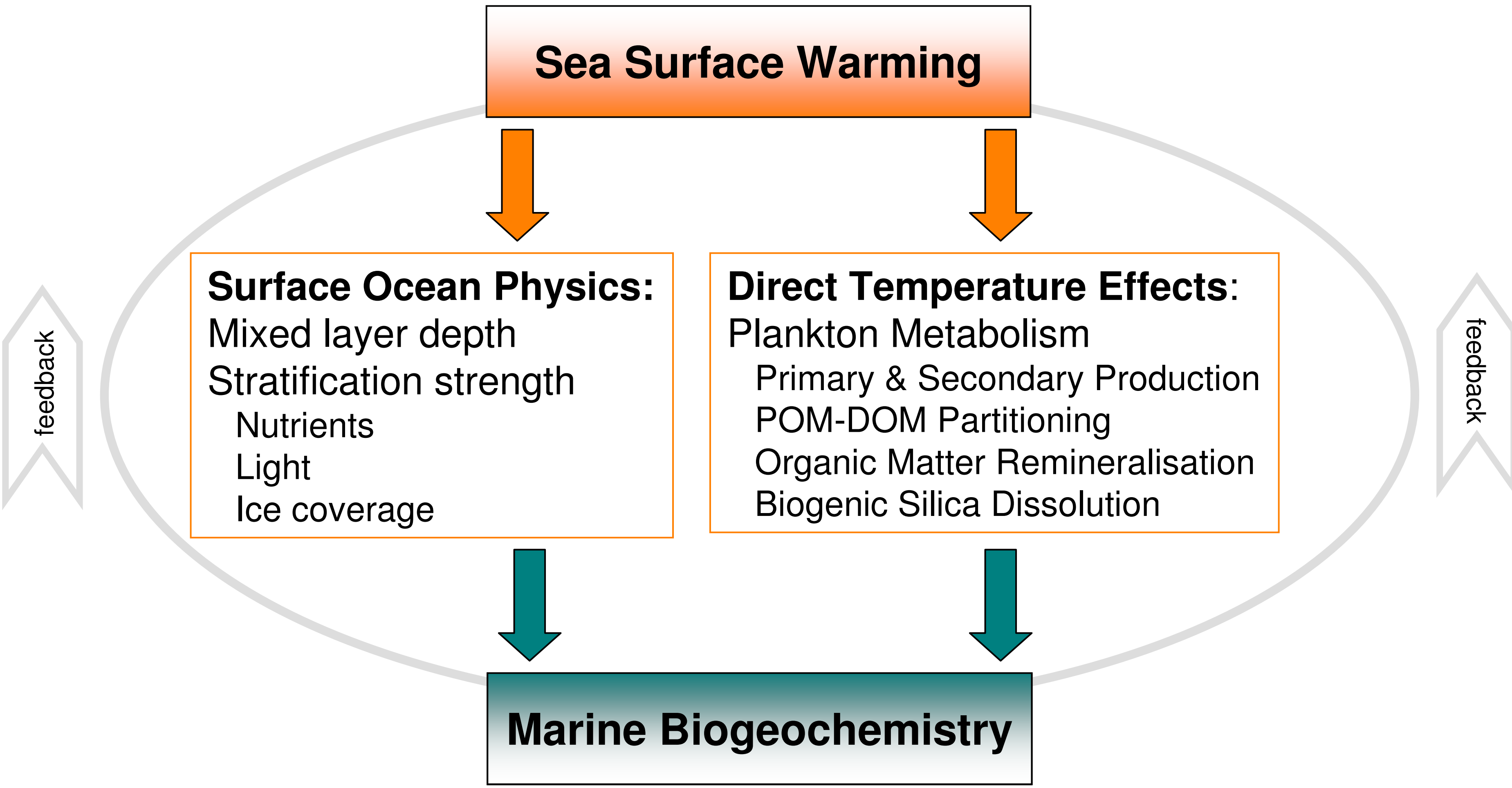
SURFACE TEMPERATURE
-PROJECTED CHANGES UNTIL 2100-



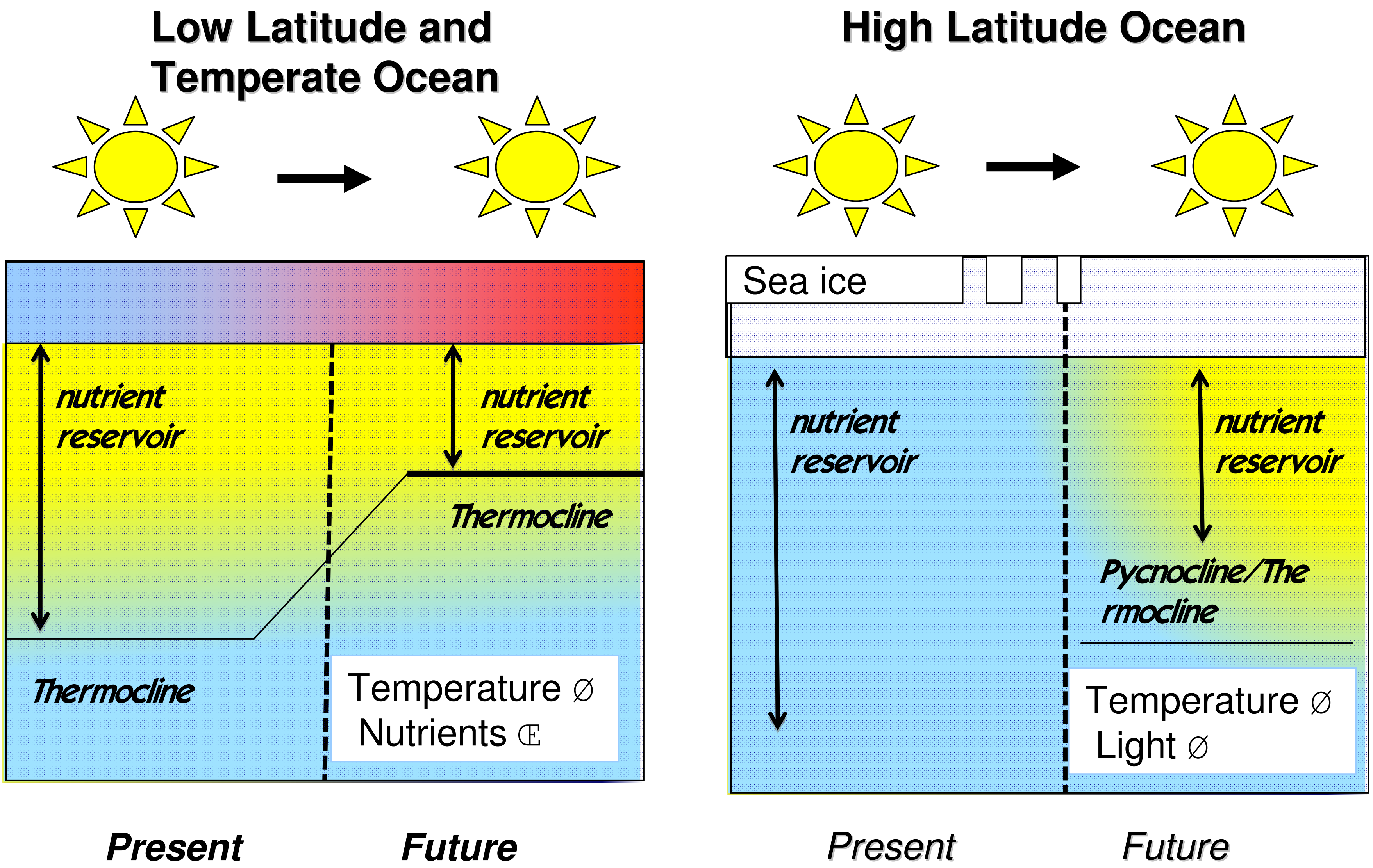
IPCC-A1F1 Scenario ‘business as usual‘

Largest temperature changes are expected for the northern hemisphere
Exceptional strong warming may occur in the Arctic Ocean

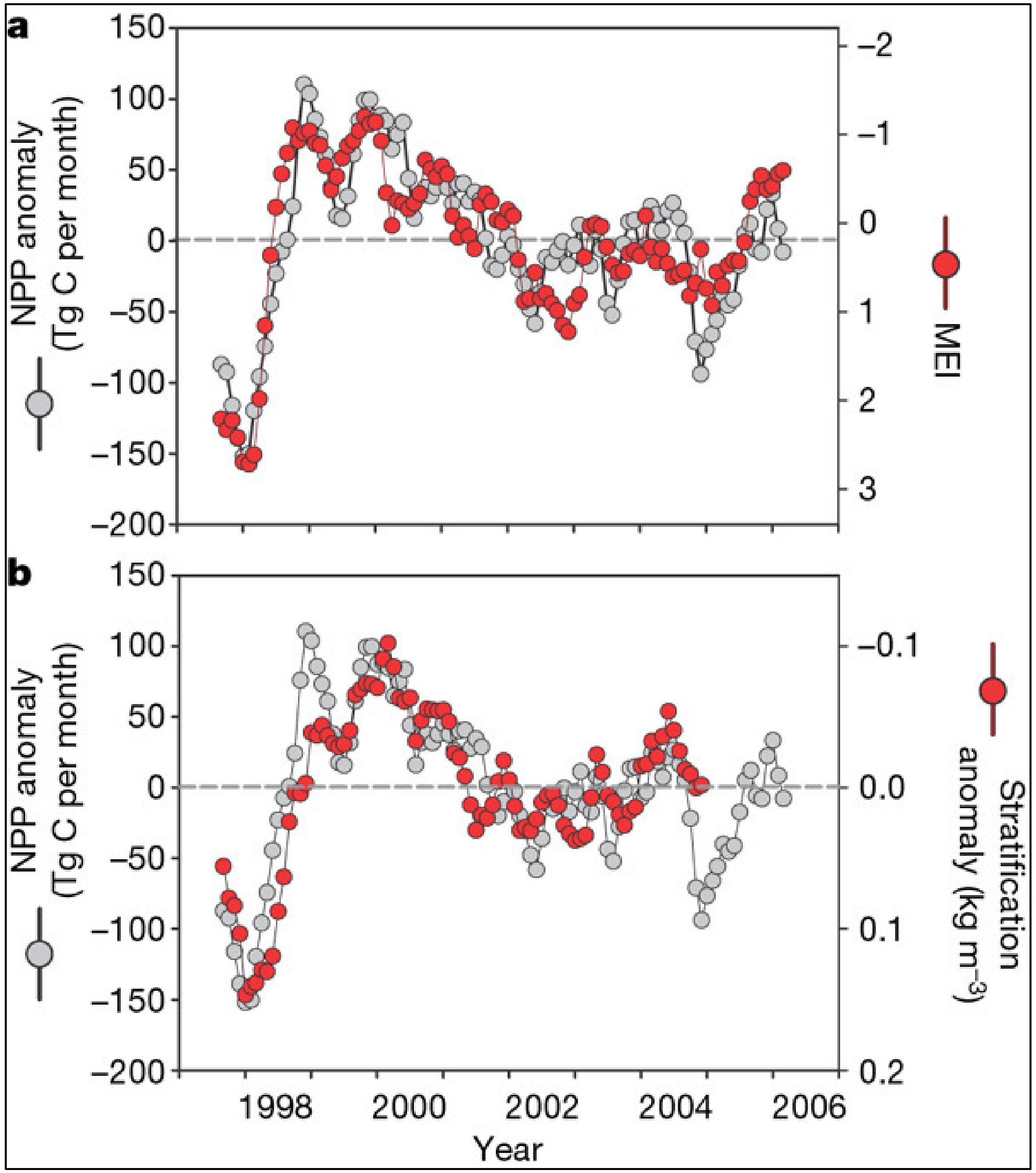
BIOGEOCHEMISTRY AND SURFACE WARMING OUTLINE:



Increase in Surface Ocean Stratification

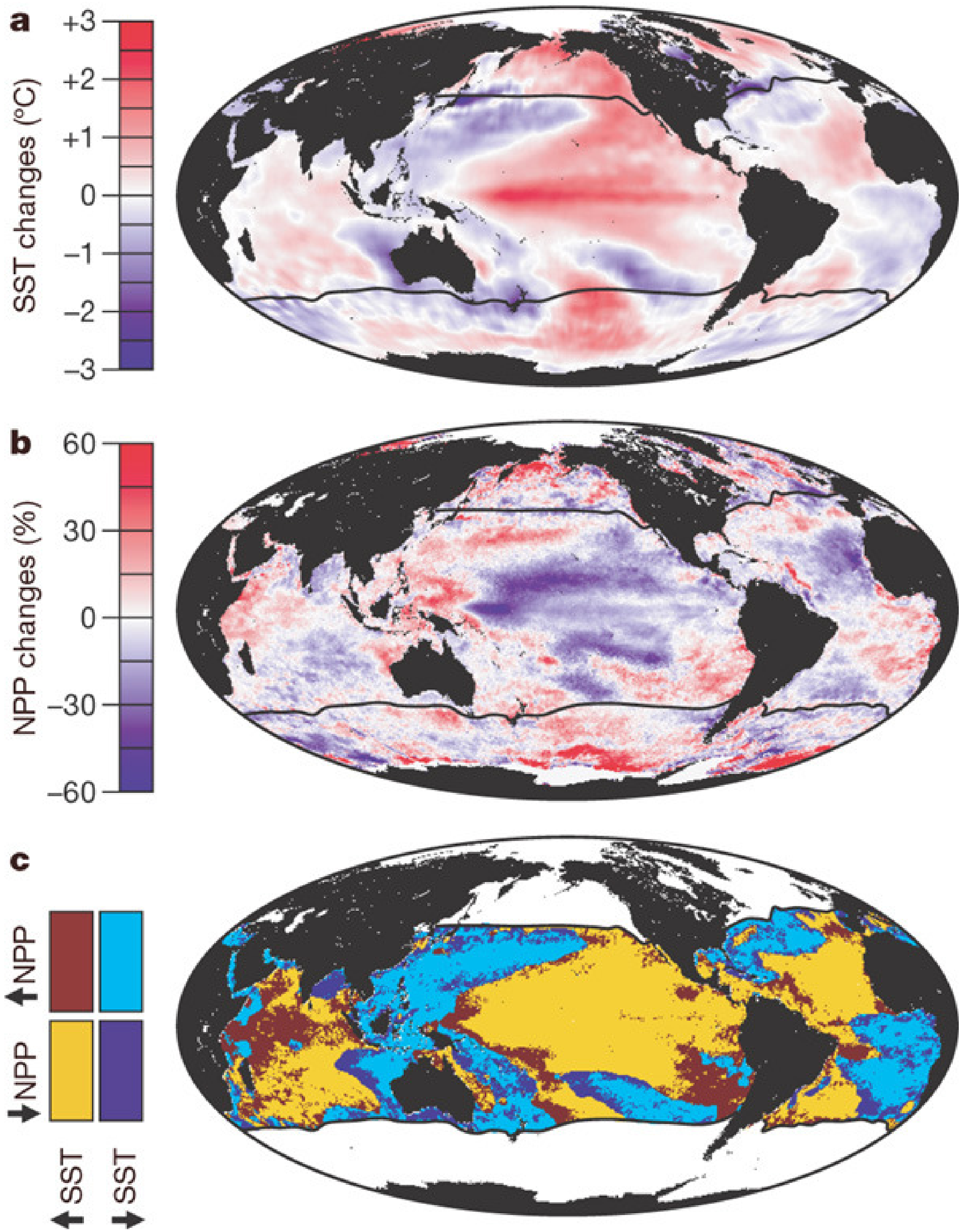


Stratification Reduces Primary Production (in warm regions)



Net primary production (NPP) anomaly follows changes in stratification patterns

Behrenfeld et al. (Nature, 2006)



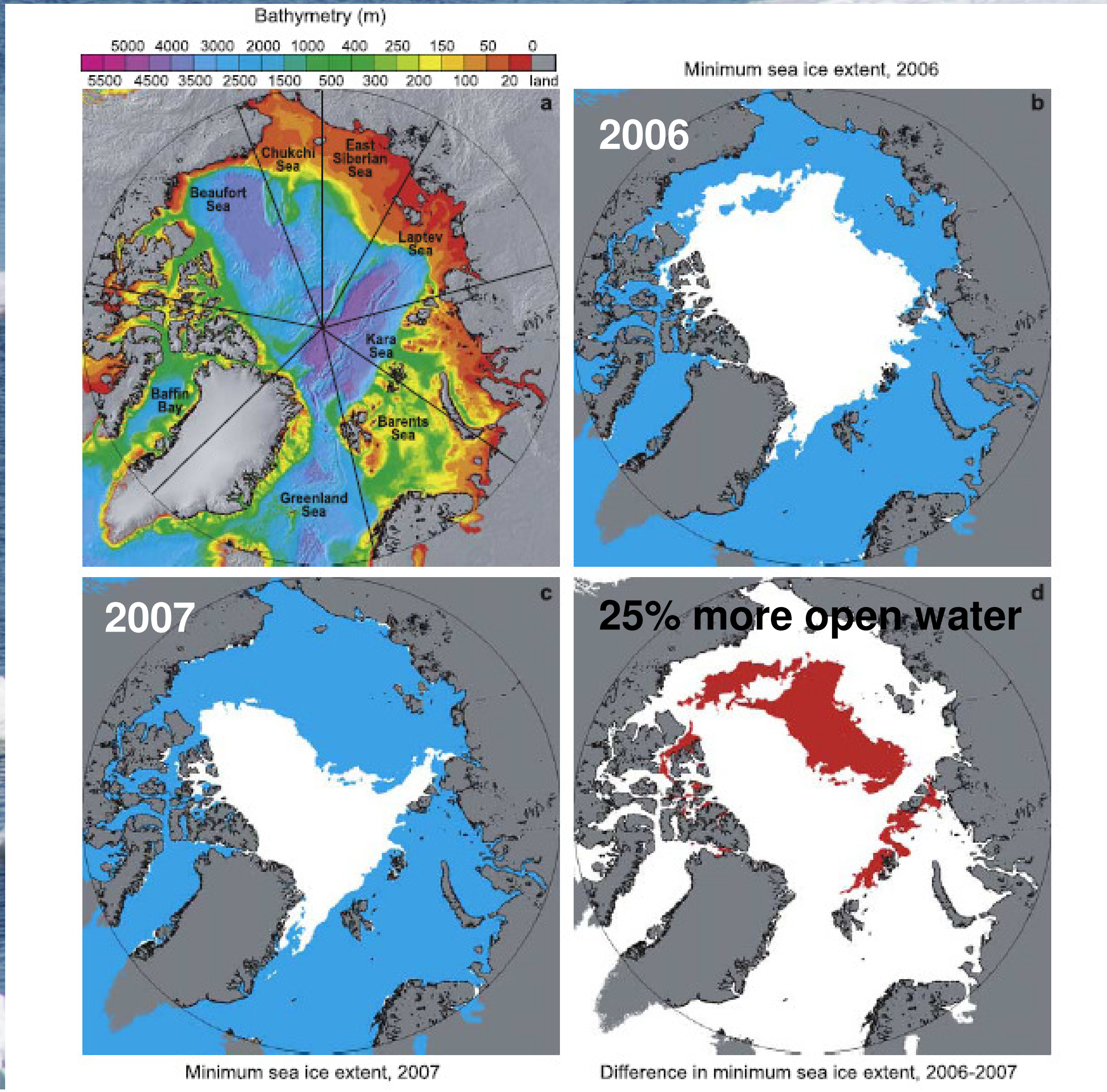
Changes in annual average **SST** between 1994 and 2004

Changes in annual average **NPP** between 1994 and 2004

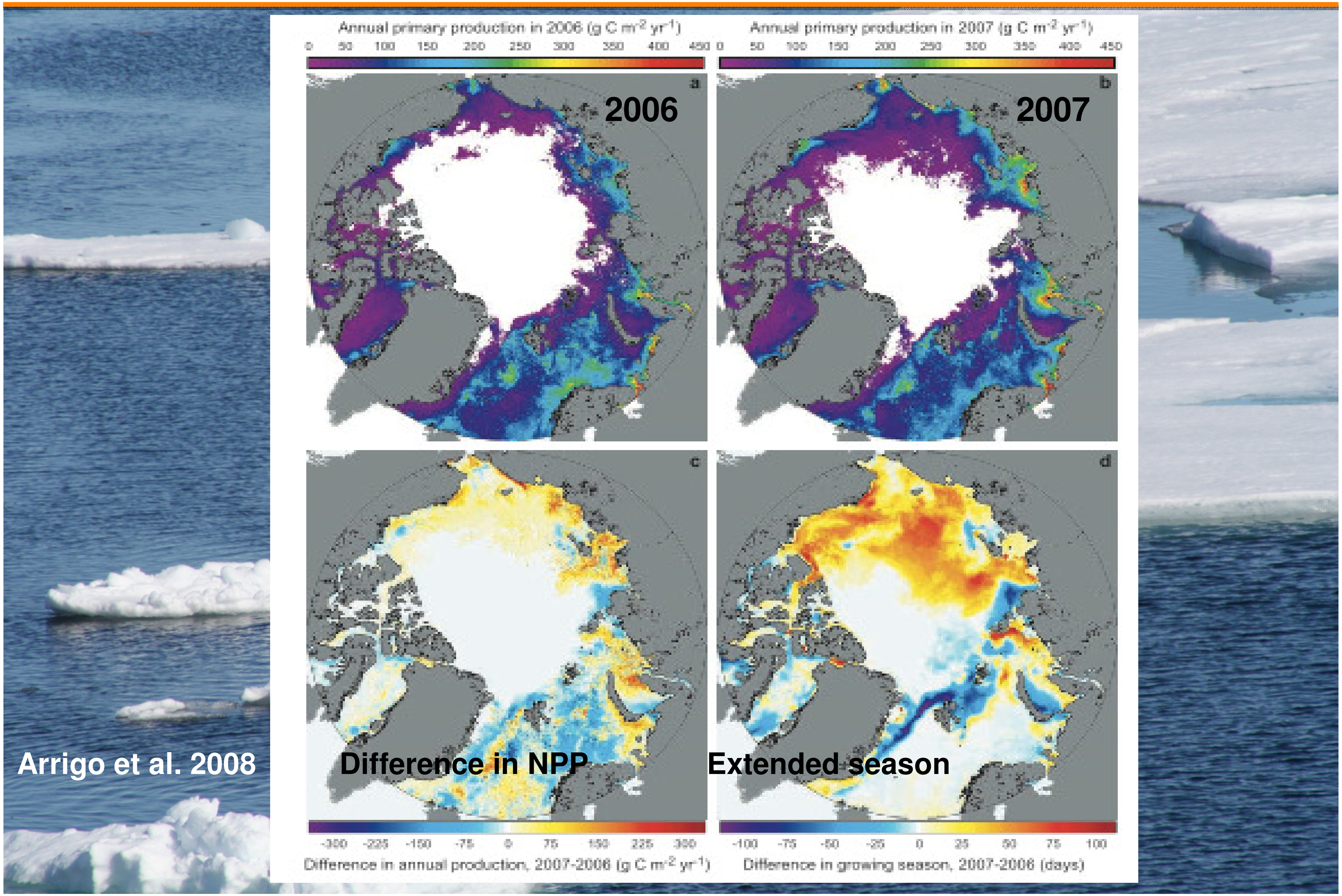
For 74% of the permanently stratified ocean, NPP and SST changes are inversely related

Behrenfeld et al. (Nature, 2006)

WHAT TO EXPECT FOR THE POLAR OCEANS?

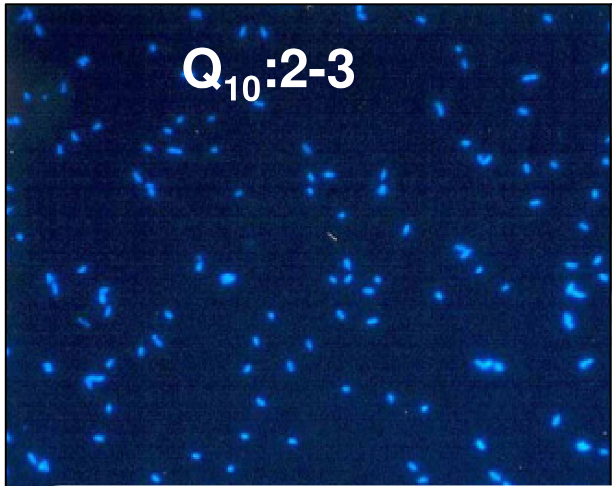


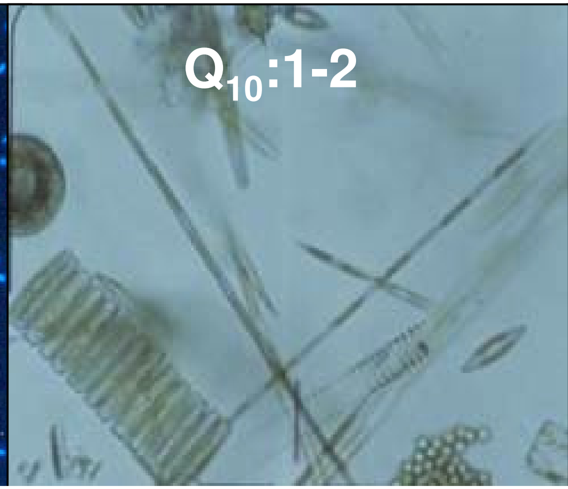
WHAT TO EXPECT FOR THE POLAR OCEANS?

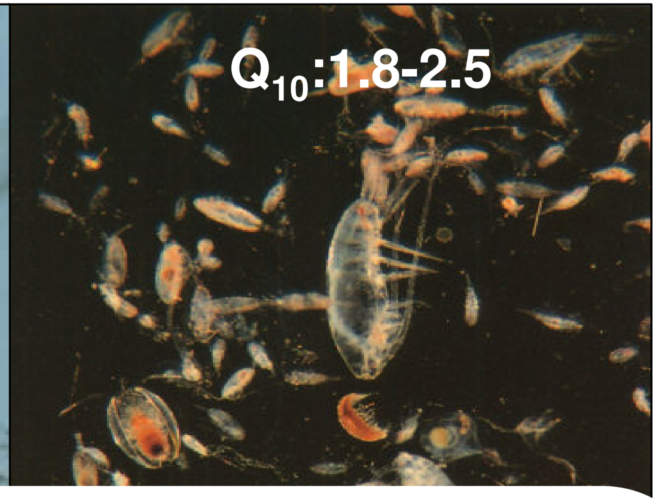


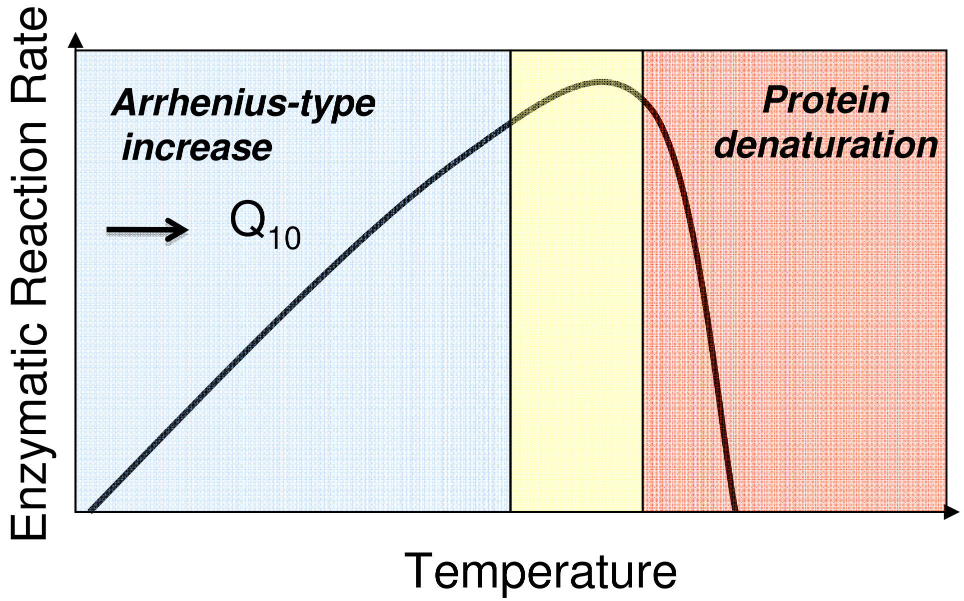
Direct Effects of Temperature on Biology
-Metabolic Processes-

Bacterioplankton	Phytoplankton	Zooplankton

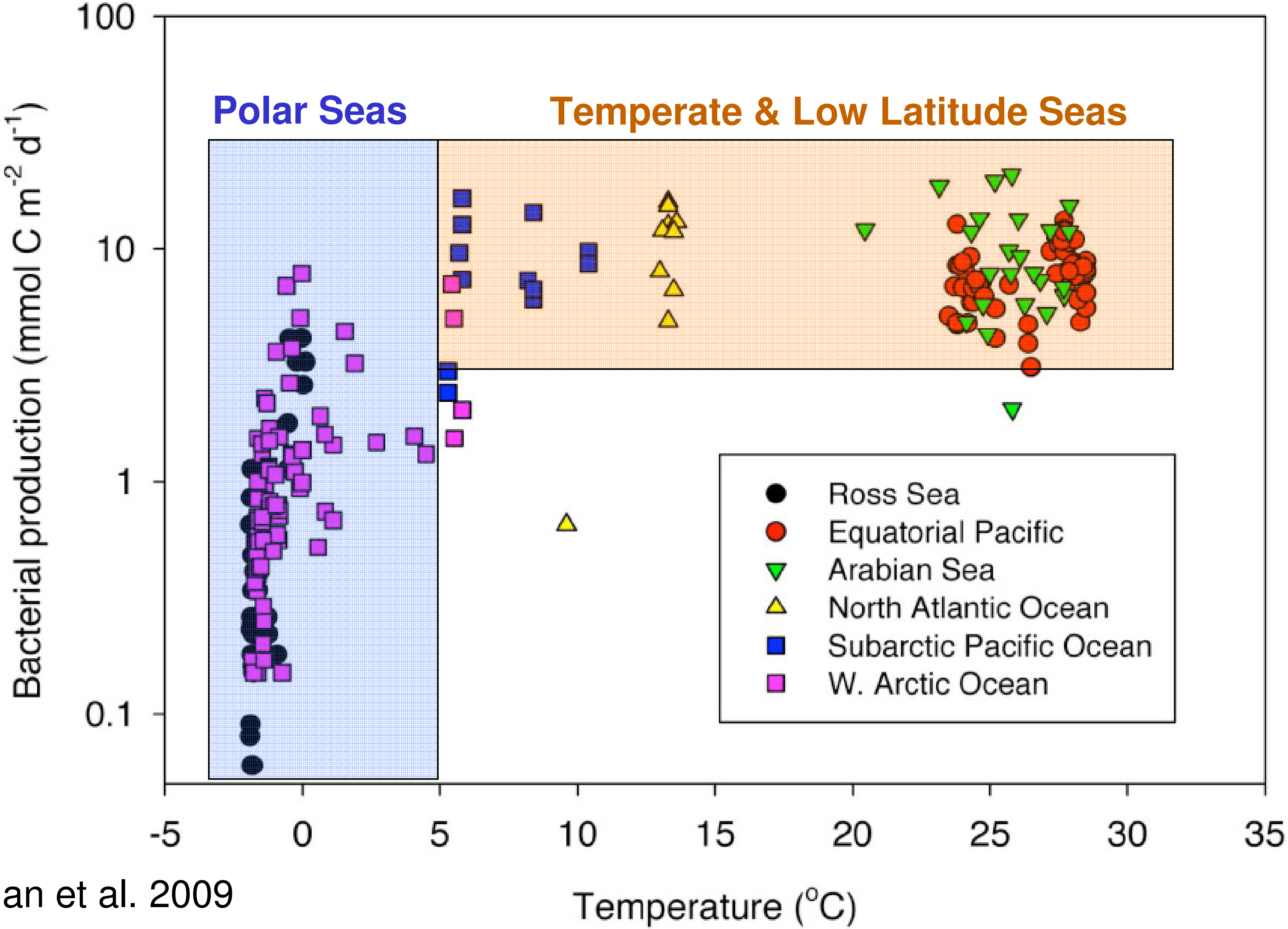






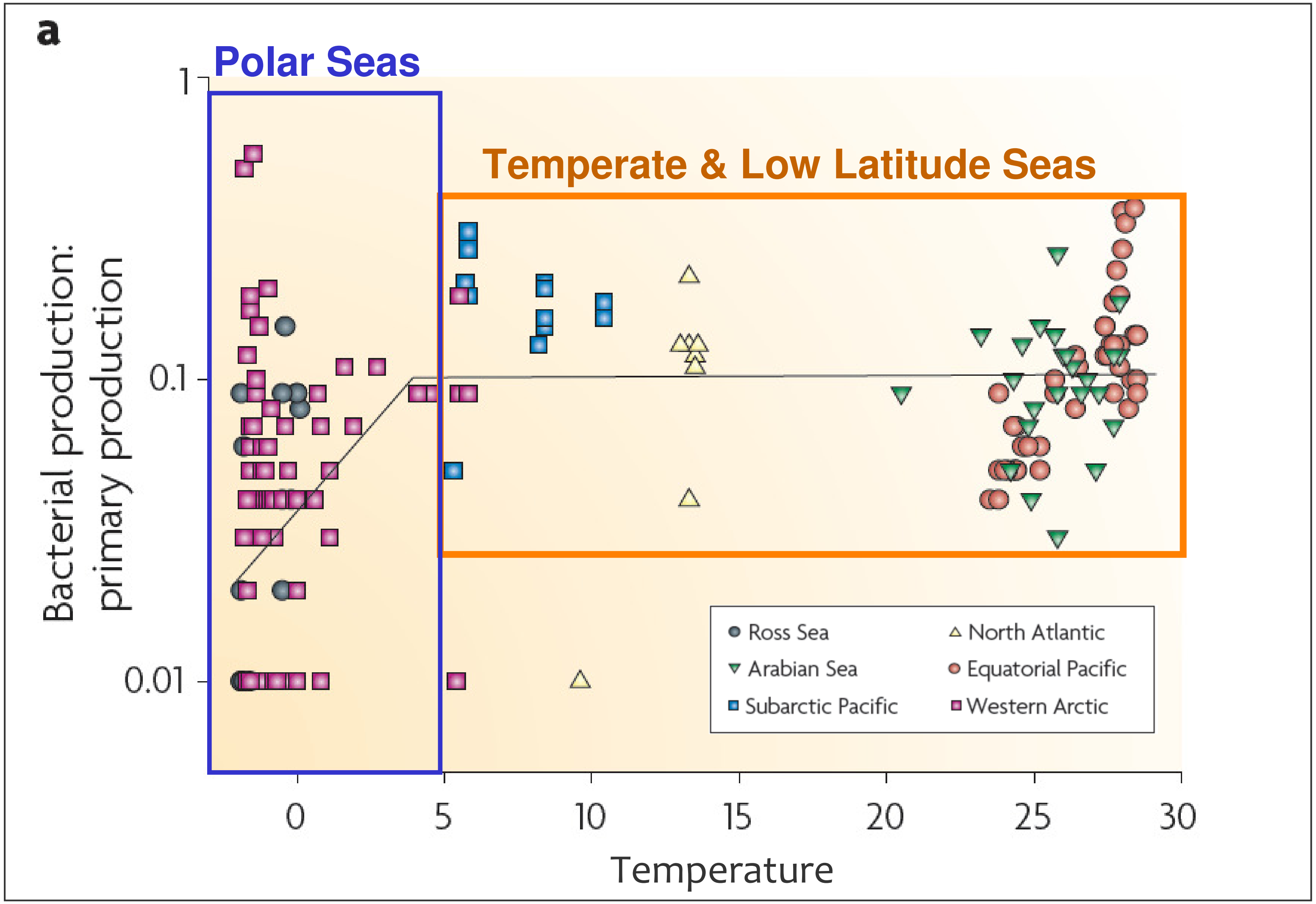


Temperature Sensitivity of Bacterial Production in the Ocean



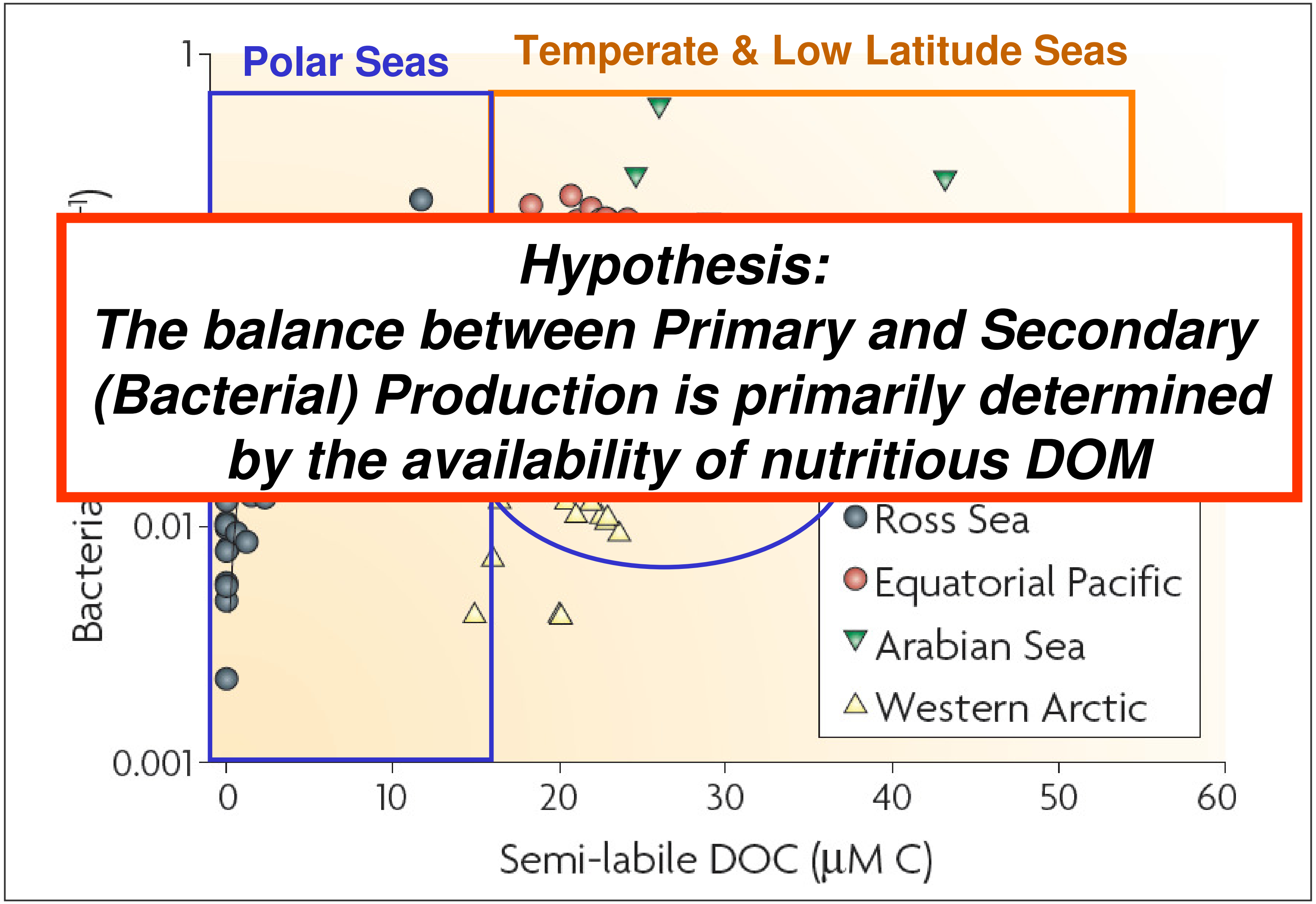
Kirchman et al. 2009

Temperature Sensitivity of Bacterial Production in the Ocean



Kirchman et al. 2009

TEMPERATURE SENSITIVITY
OF BACTERIAL PRODUCTION IN THE OCEAN ?



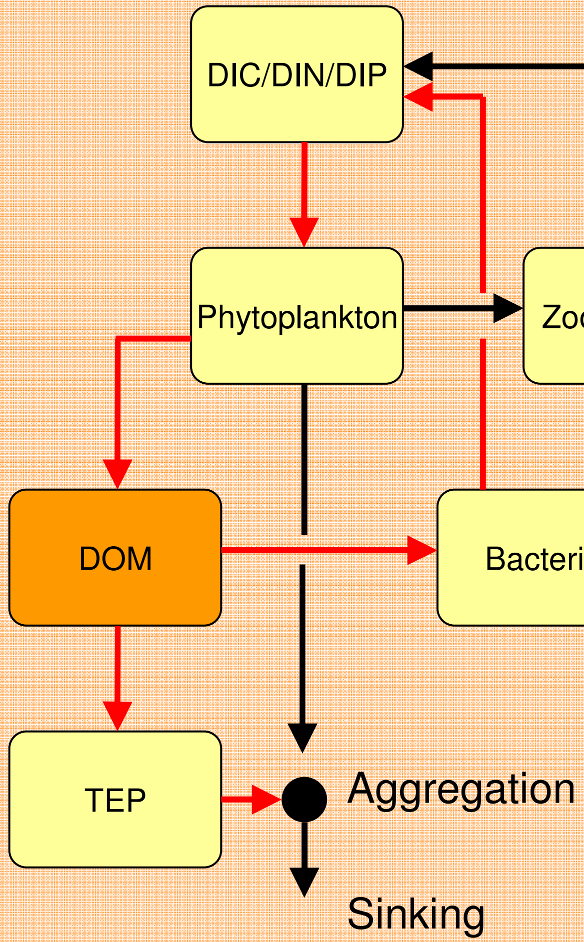
Hypothesis:
The balance between Primary and Secondary (Bacterial) Production is primarily determined by the availability of nutritious DOM

Kirchman et al. 2009

AQUA SHIFT (2005-2010)

Project: Temperature Effects on DOM-POM-Partitioning

Riebesell & Engel



- *Source of DOM: - Phytoplankton*
- *Sink of DOM: - Bacterial Production*
  - DOM aggregation

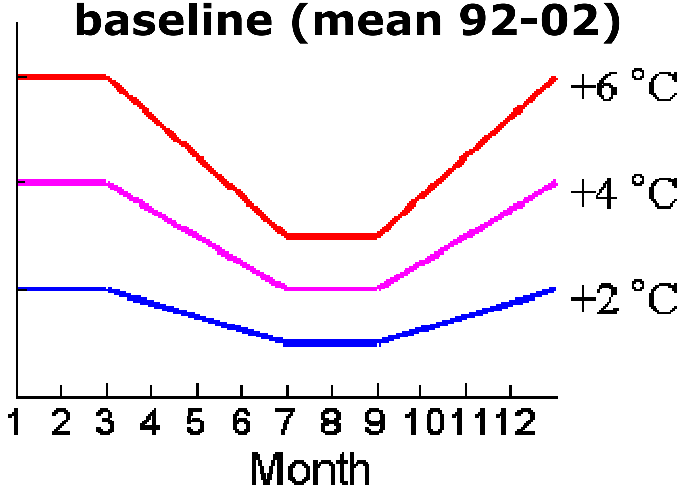
- *DOM sinks and sources display different temperature-sensitivities*

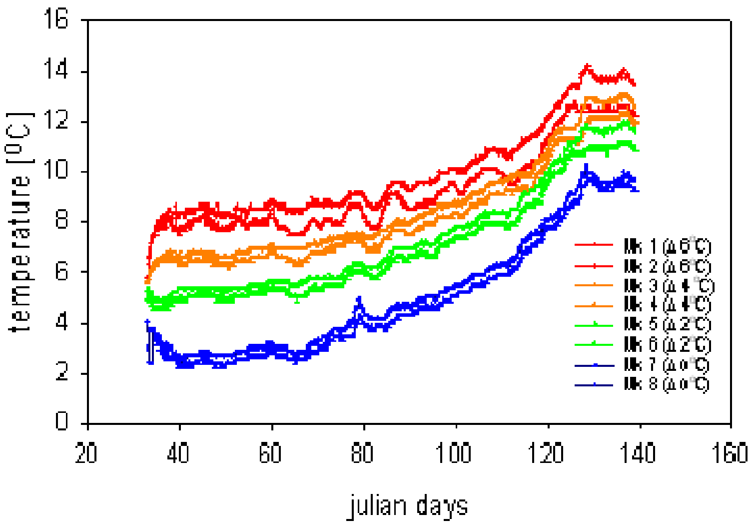
Hypothesis:
DOM-POM partitioning is temperature-sensitive

AQUASHIFT:

EXPERIMENTAL DESIGN OF MESOCOSM STUDIES

temperature increase above baseline (mean 92-02)

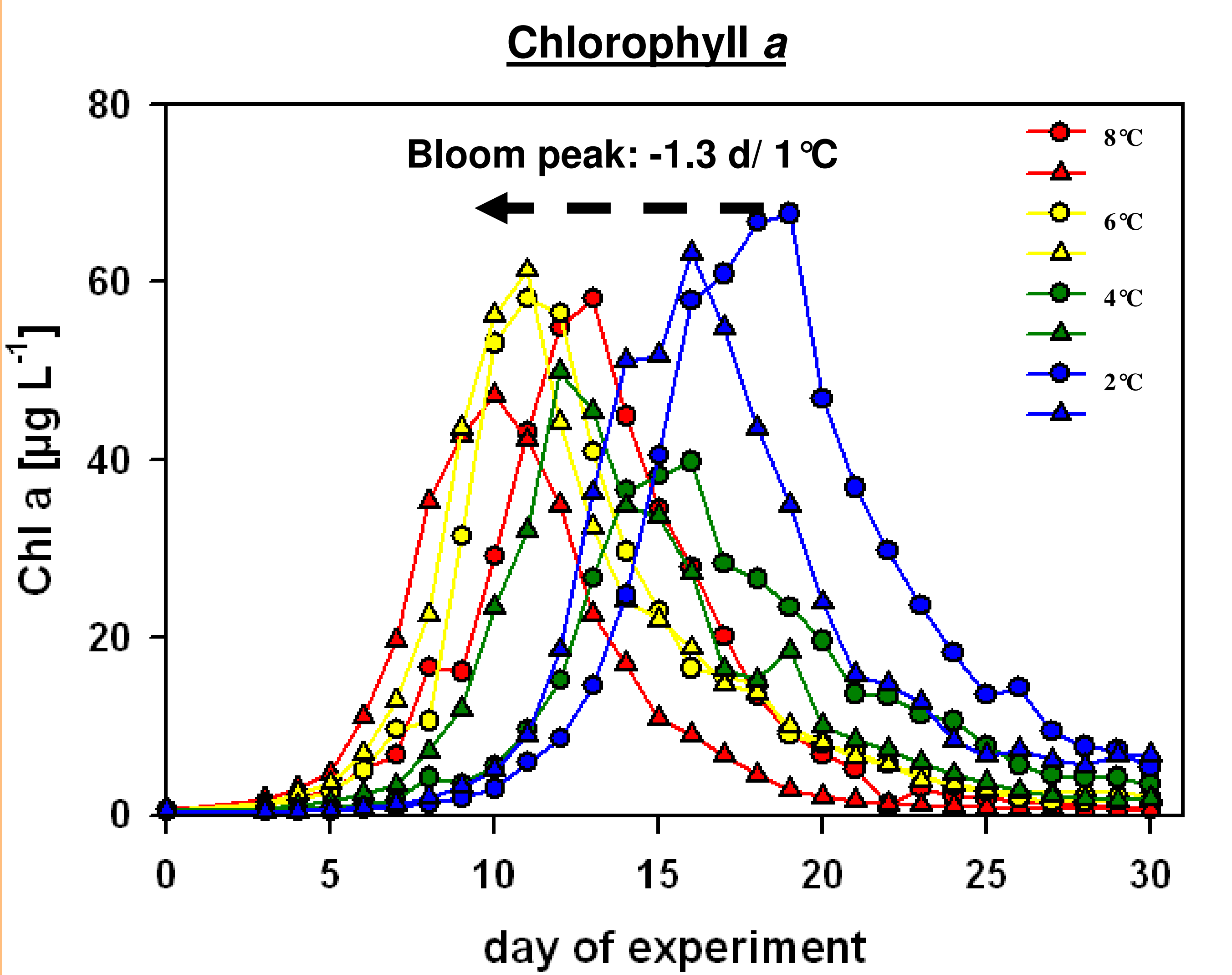




actual temperatures

Sommer et al (2007)

AQUASHIFT:
Temperature effect on phytoplankton blooms

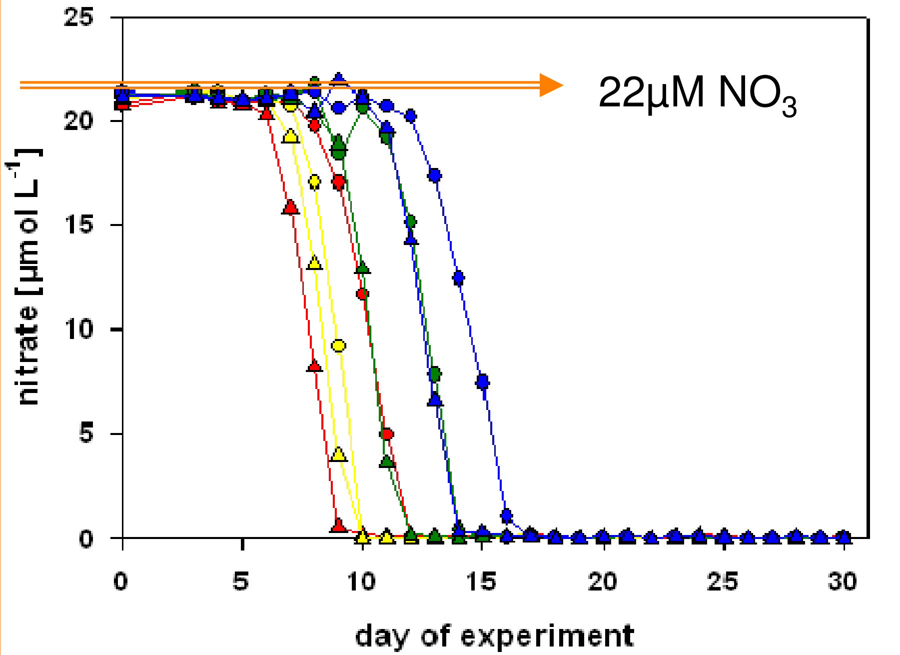


Wohlers et al. (2009)

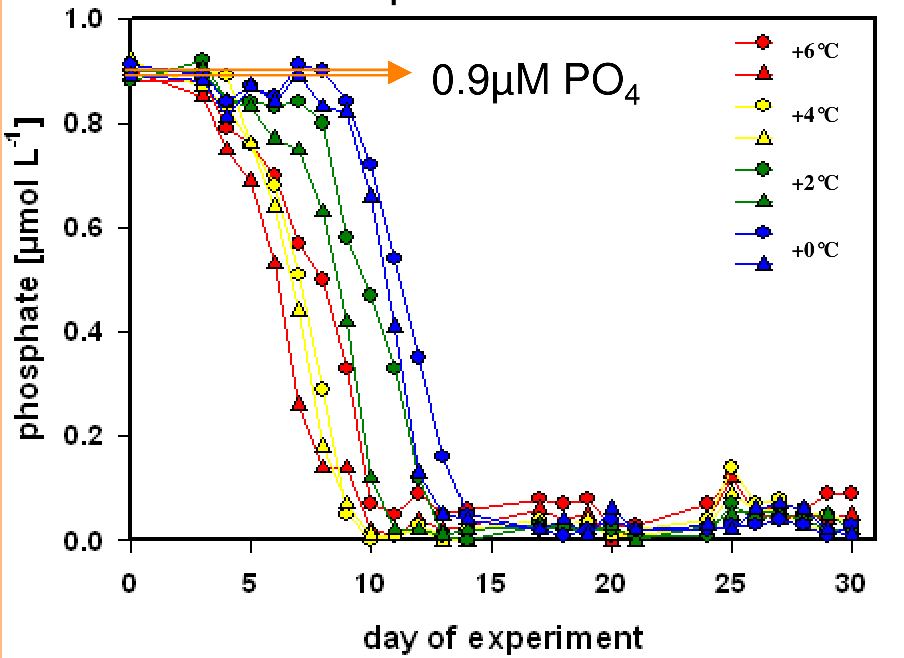
AQUASHIFT:
Temperature effect on phytoplankton blooms

Temperature accelerates nutrient draw-down

Nitrate: -1d/°C



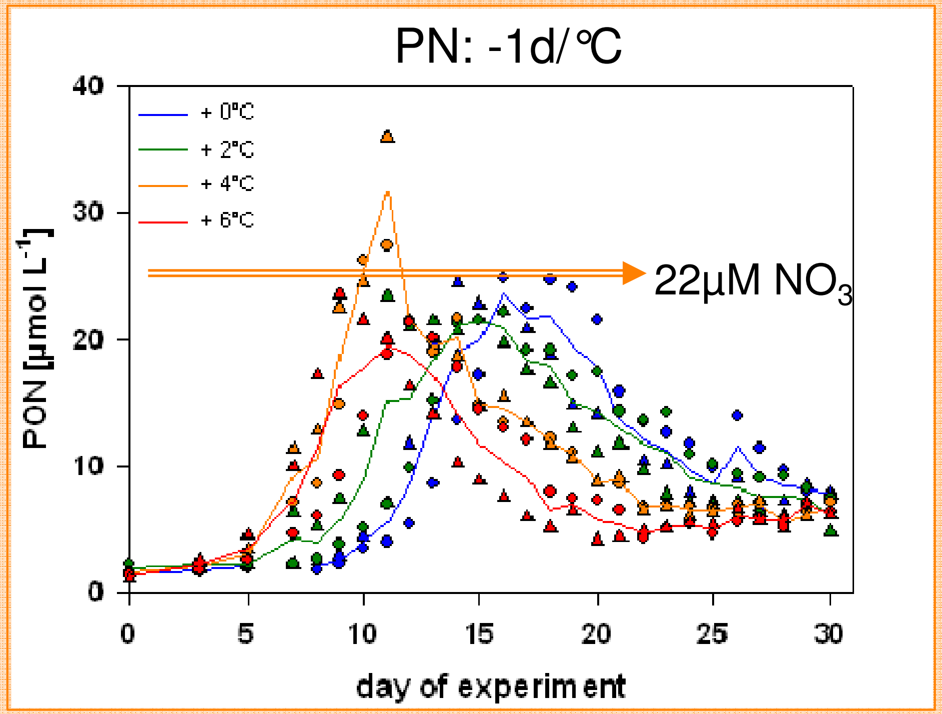
Phosphate: -0.7d/°C

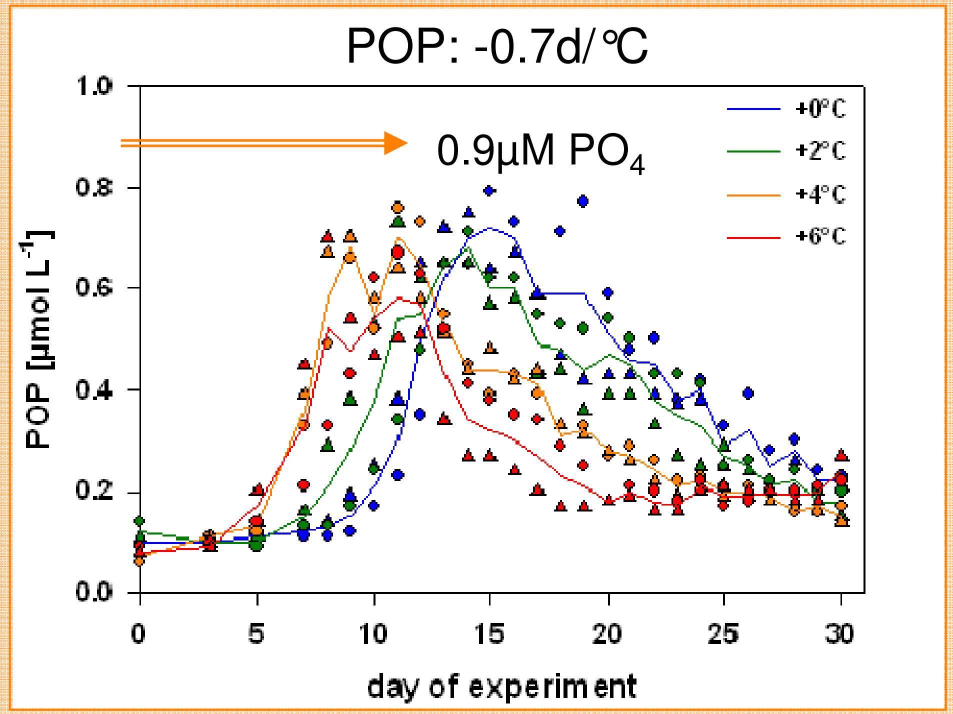


Wohlers et al. (2009)

AQUASHIFT:
Temperature effect on phytoplankton blooms

No temperature effect on total yield of PN and POP





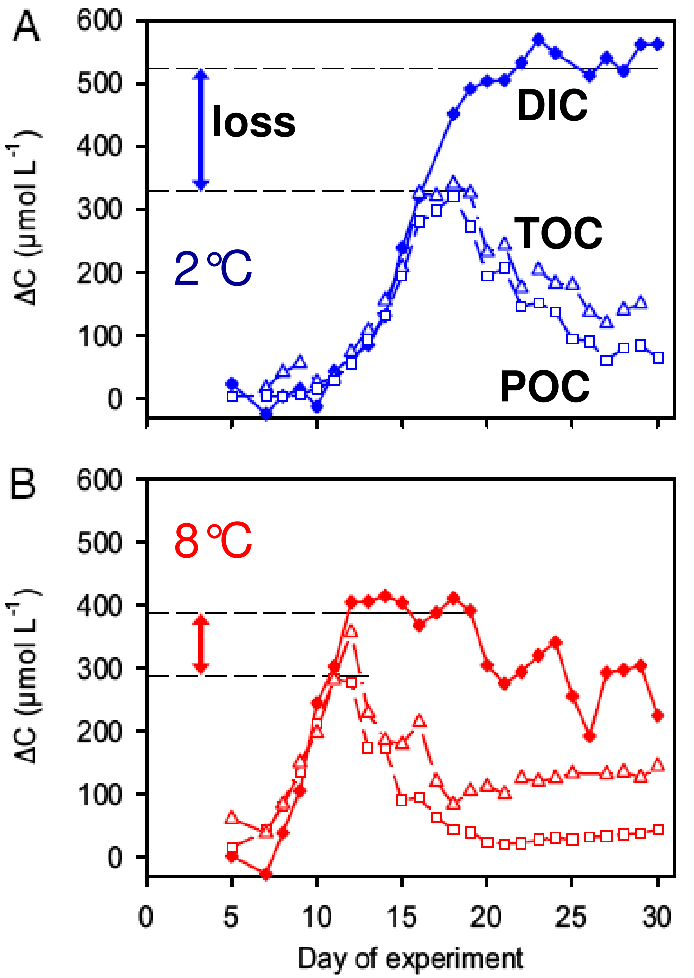
Wohlers et al. (2009)

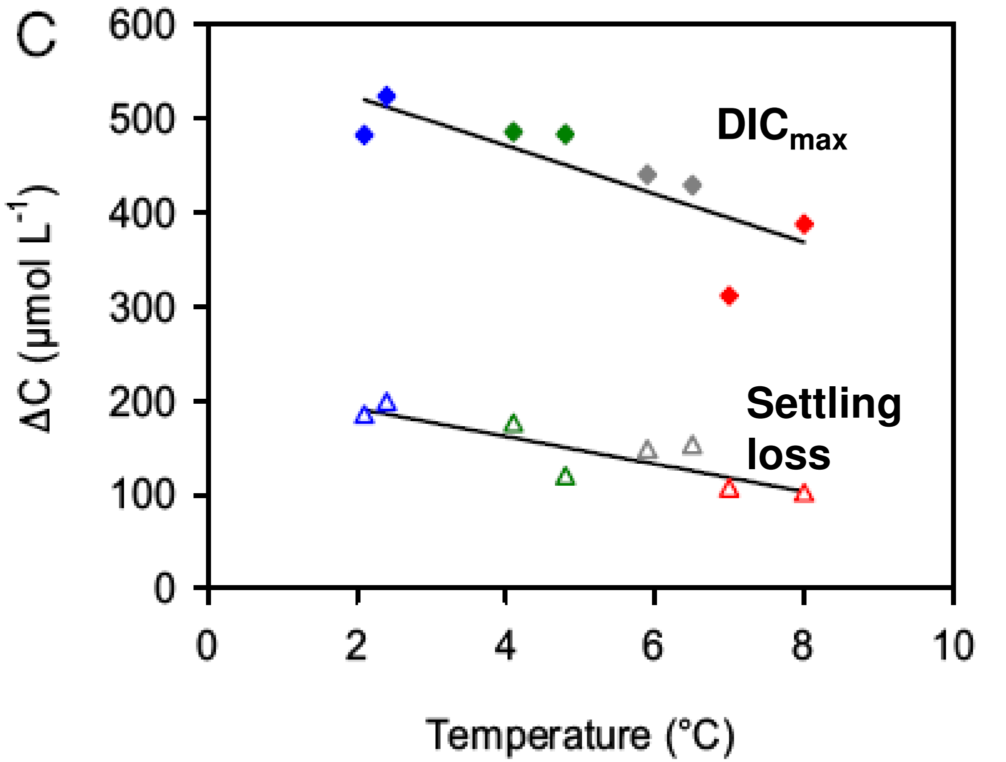
Changes in biogenic carbon flow in response to sea surface warming

Julia Wohlers[a,1], Anja Engel[b], Eckart Zöllner[a], Petra Breithaupt[c], Klaus Jürgens[d], Hans-Georg Hoppe[c], Ulrich Sommer[e], and Ulf Riebesell[a]

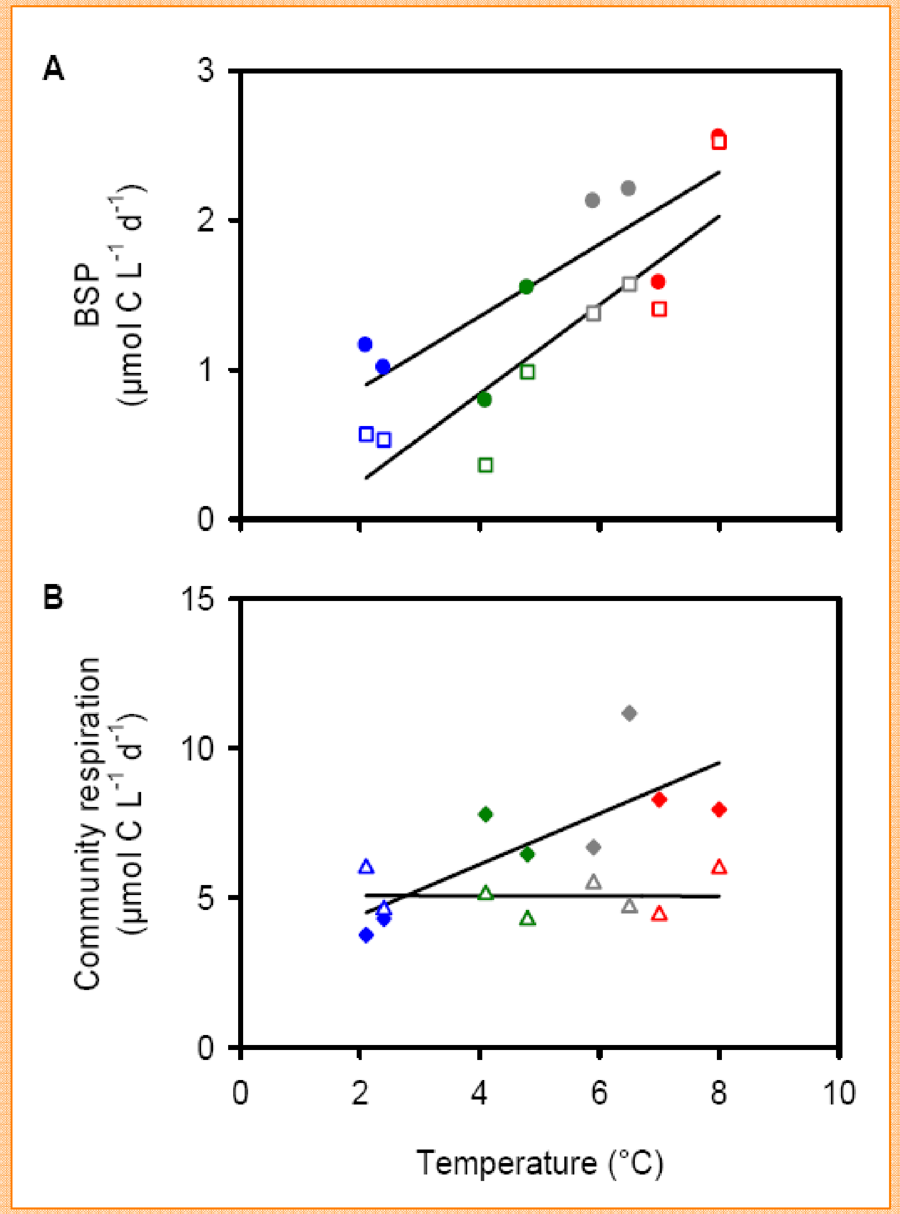
Departments of [a]Biological Oceanography, [c]Microbial Ecology, and [e]Experimental Ecology, IFM-GEOMAR Leibniz Institute of Marine Sciences, Düsternbrooker Weg 20, 24105 Kiel, Germany; [b]Department of Biological Oceanography, Alfred Wegener Institute for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany; and [d]Department of Biological Oceanography, Leibniz Institute for Baltic Sea Research Warnemünde, Seestrasse 15, 18119 Rostock, Germany

Edited by David M. Karl, University of Hawaii, Honolulu, HI, and approved March 9, 2009 (received for review December 18, 2008)





Temperature control of heterotrophy

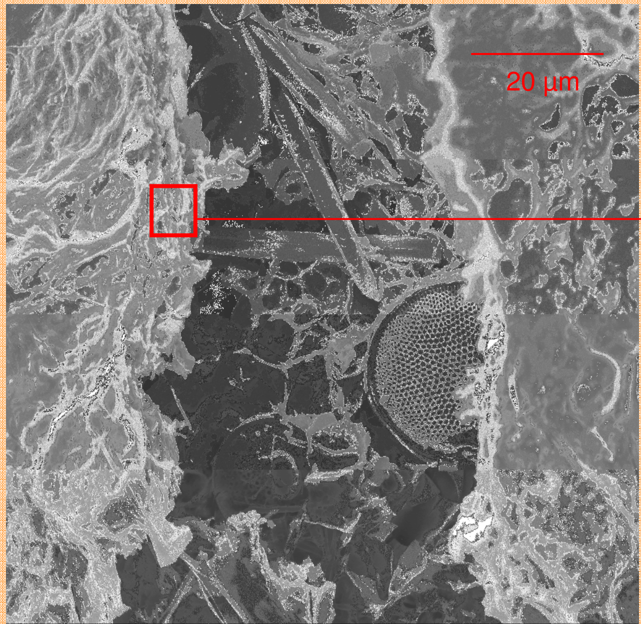


Bacterial Secondary Production increases with temperature

Community Respiration >3µm increases with temperature

Wohlers et al. (2009)

ORGANIC MATTER DEGRADATION IN AGGREGATES



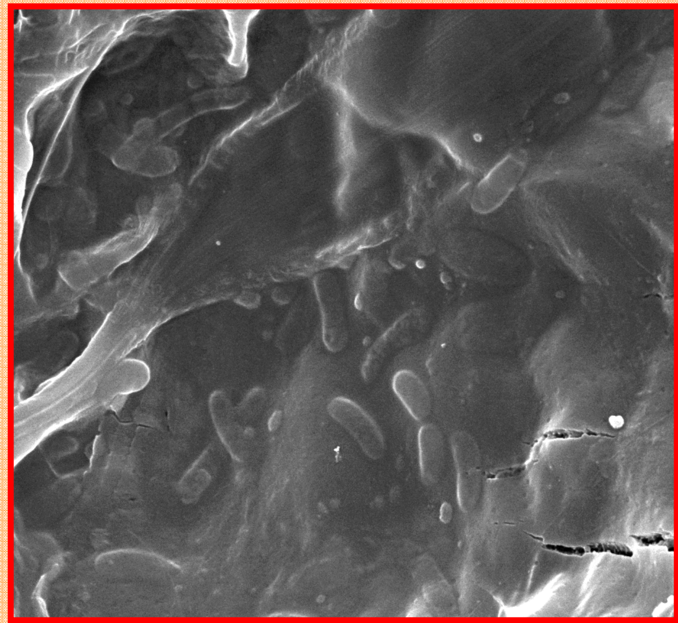
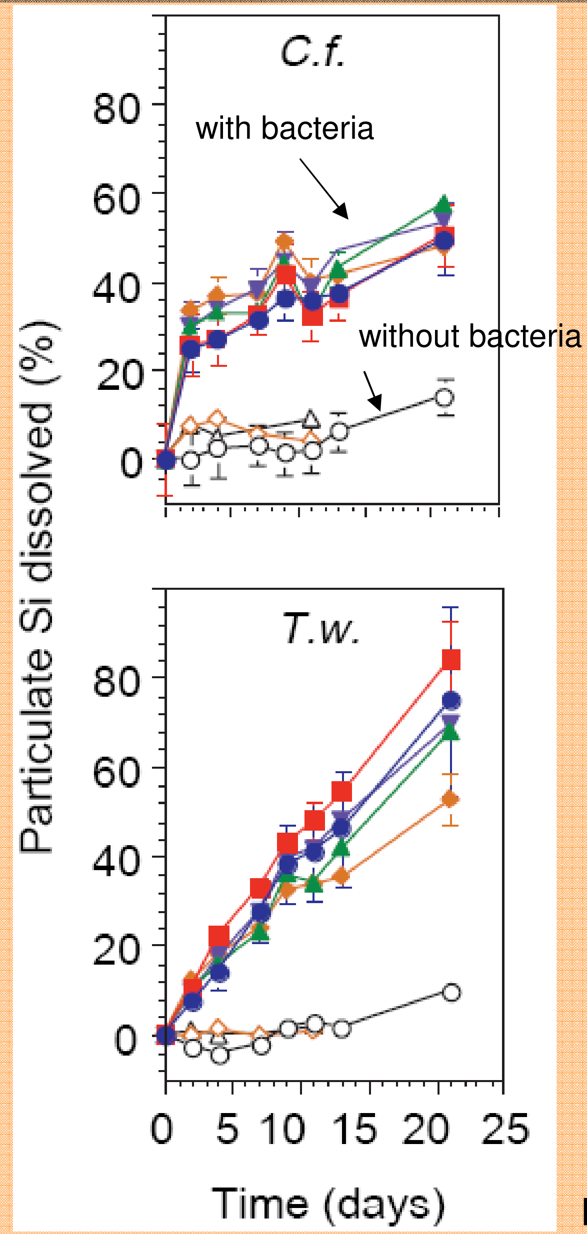


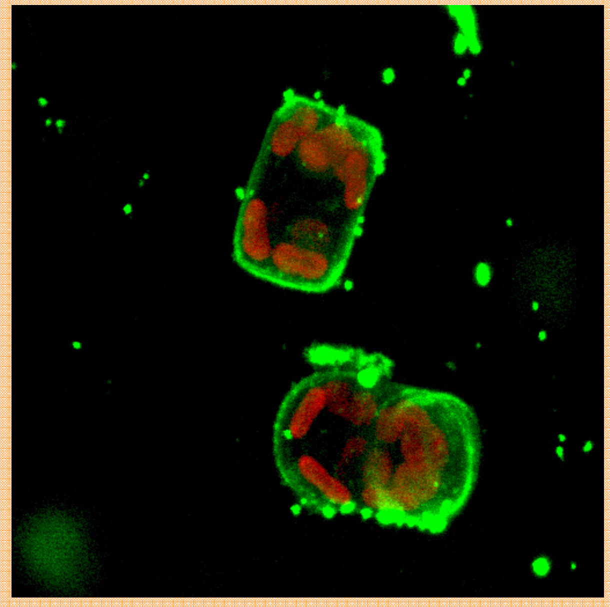
Table 3. Activity of extracellular enzymes associated with aggregates. The enhancement factors $I_{V\max}$ and $I_{V\max/Km}$ were calculated according to Eq. (7). Values are means ± SD of duplicate incubations per temperature over time. *Significant differences between temperature treatments ($p < 0.05$). AGG: aggregates

Enzyme	$V_{\max}$ [nmol (ml AGG)$^{-1}$ h^{-1}] 8.5°C	$V_{\max}$ [nmol (ml AGG)$^{-1}$ h^{-1}] 2.5°C	$I_{V\max}$	$V_{\max}/K_m$ (h^{-1}) 8.5°C	$V_{\max}/K_m$ (h^{-1}) 2.5°C	$I_{V\max/Km}$
α-glucosidase	7.0 ± 1.5	4.5 ± 0.15	1.6	0.20 ± 0.02	0.05 ± 0.01	4.0*
β-glucosidase	21.0 ± 1.3	5.0 ± 0.10	4.2*	0.65 ± 0.13	0.05 ± 0.01	13.0*
Leucine-aminopeptidase	386 ± 62	66.5 ± 4.0	5.8*	9.0 ± 1.0	3.0 ± 0.20	3.0*
Alkaline phosphatase	221 ± 14	169 ± 37	1.3	108 ± 21.0	118 ± 0.20	0.9

Piontek et al (AME, 2009)

REMINERALISATION OF BIOGENIC SILICA

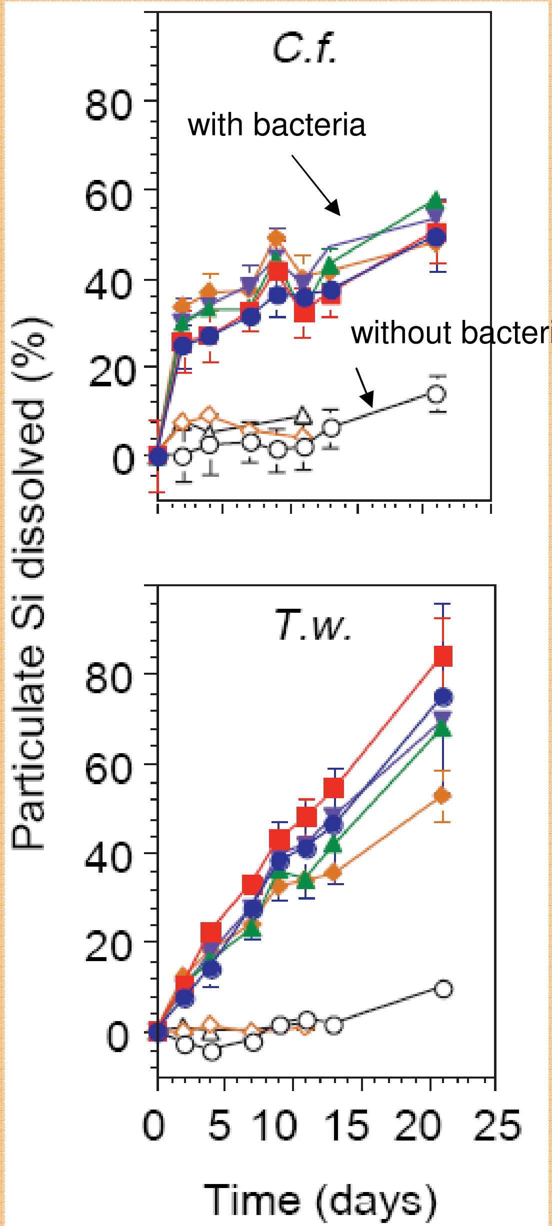




Faster dissolution of silica from diatom frustules
after bacterial degradation of organic surface coating

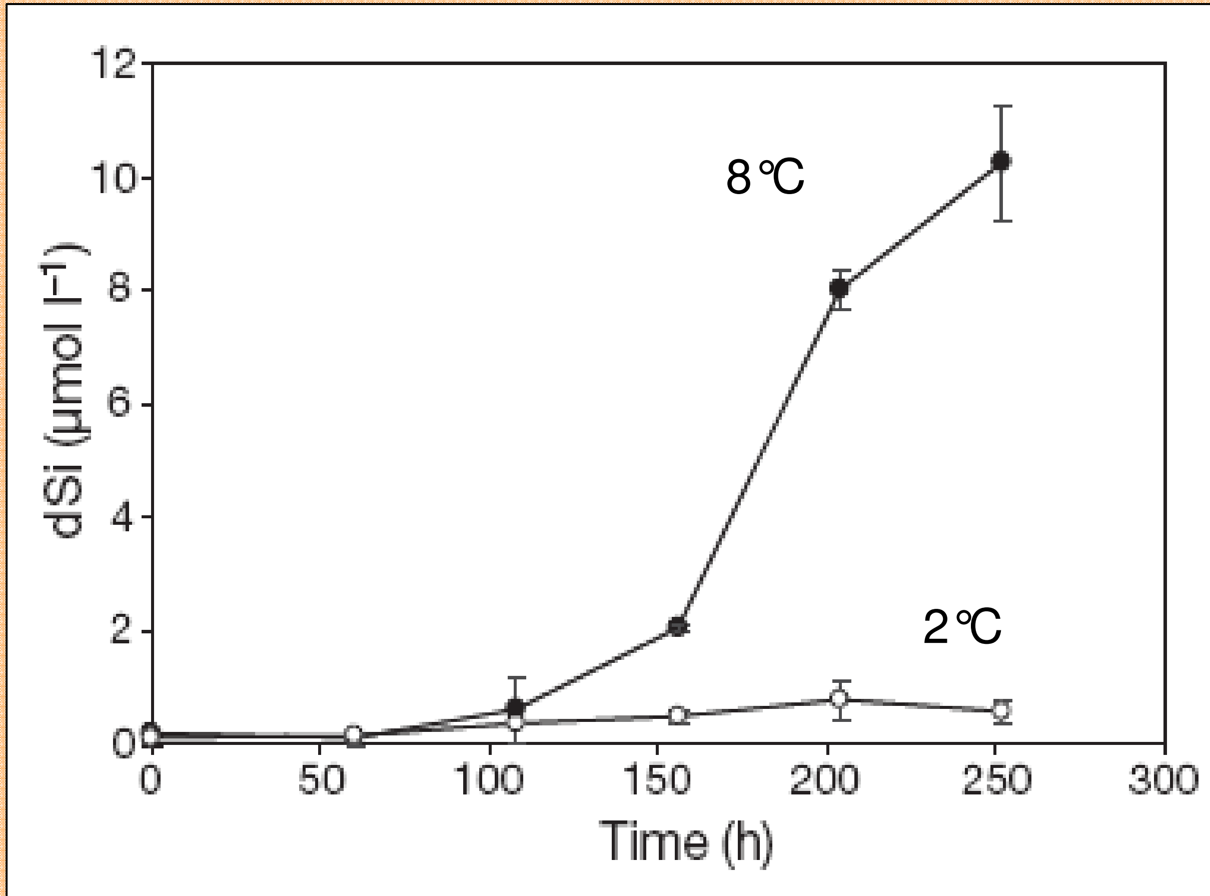
Bidle & Azam (Nature 1999)

Remineralisation of biogenic silica



Bidle & Azam (Nature 1999)

Dissolution of diatom frustules



Piontek et al (AME, 2009)

WHAT WE LEARNED FROM AQUASHIFT:

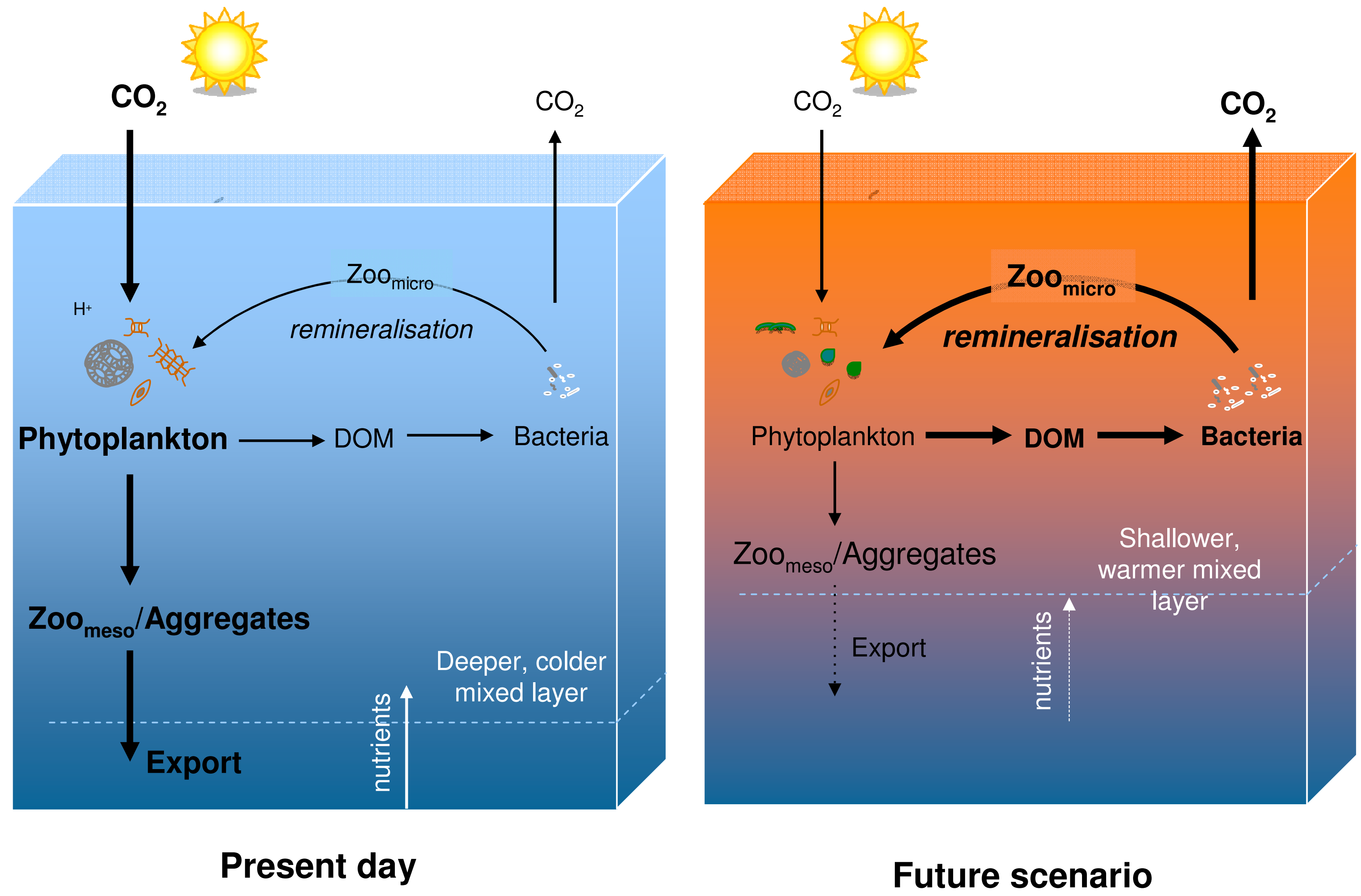
Warming leads to:

- **Higher partitioning** of carbon into **DOM** that satisfies increased bacterial carbon demand and supports microbial **metabolic activity** (growth & remineralisation).

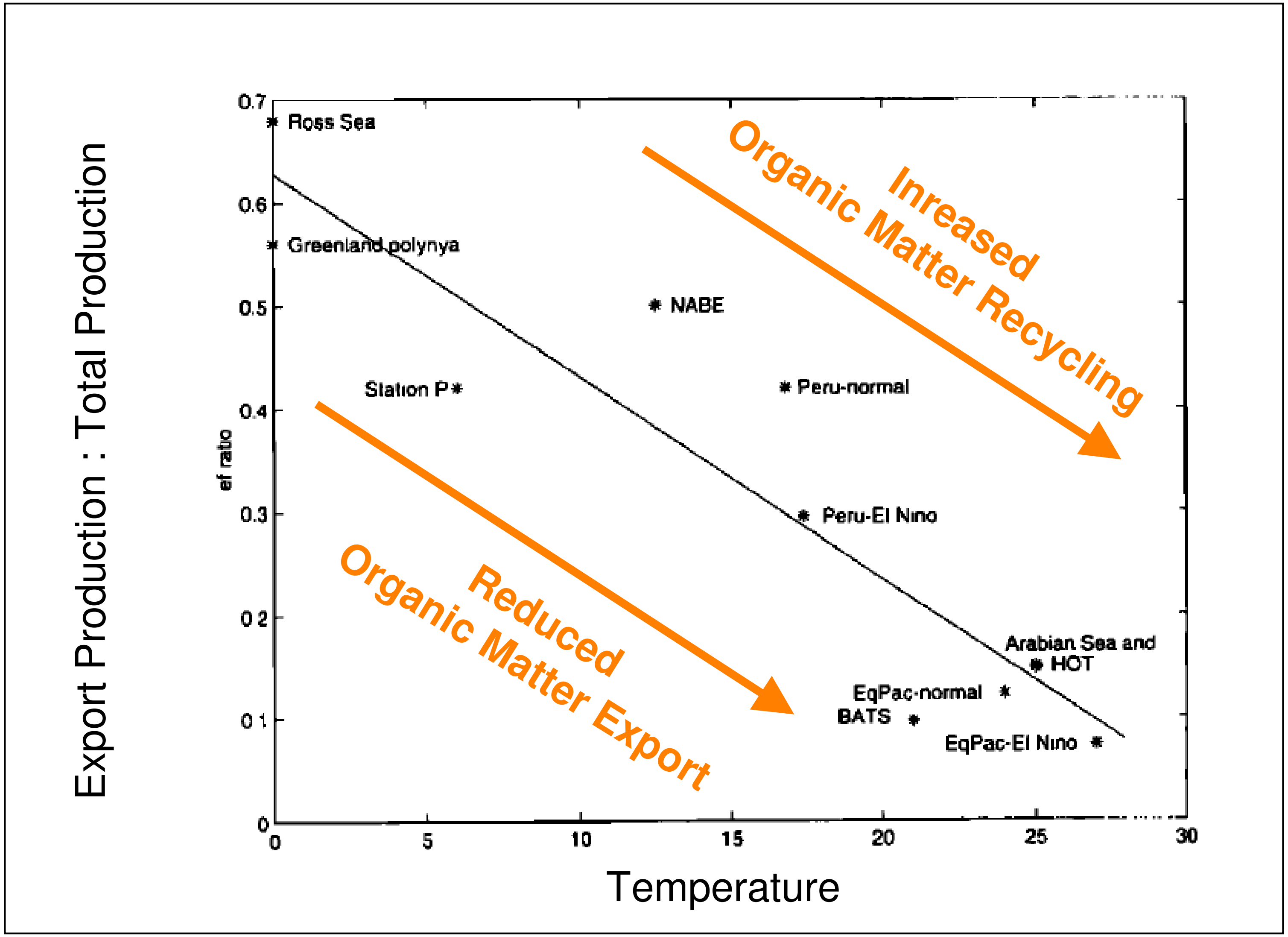
- **Earlier onset** and **higher activity** of microbial heterotrophic community that enhances organic matter **remineralisation** and reduces net DIC draw down.

- Stimulation of **microbial loop** that results in **reduced carbon export** (particularly for cold system).

SUMMARY:
WARMING EFFECTS ON BIOGEOCHEMICAL CYCLING

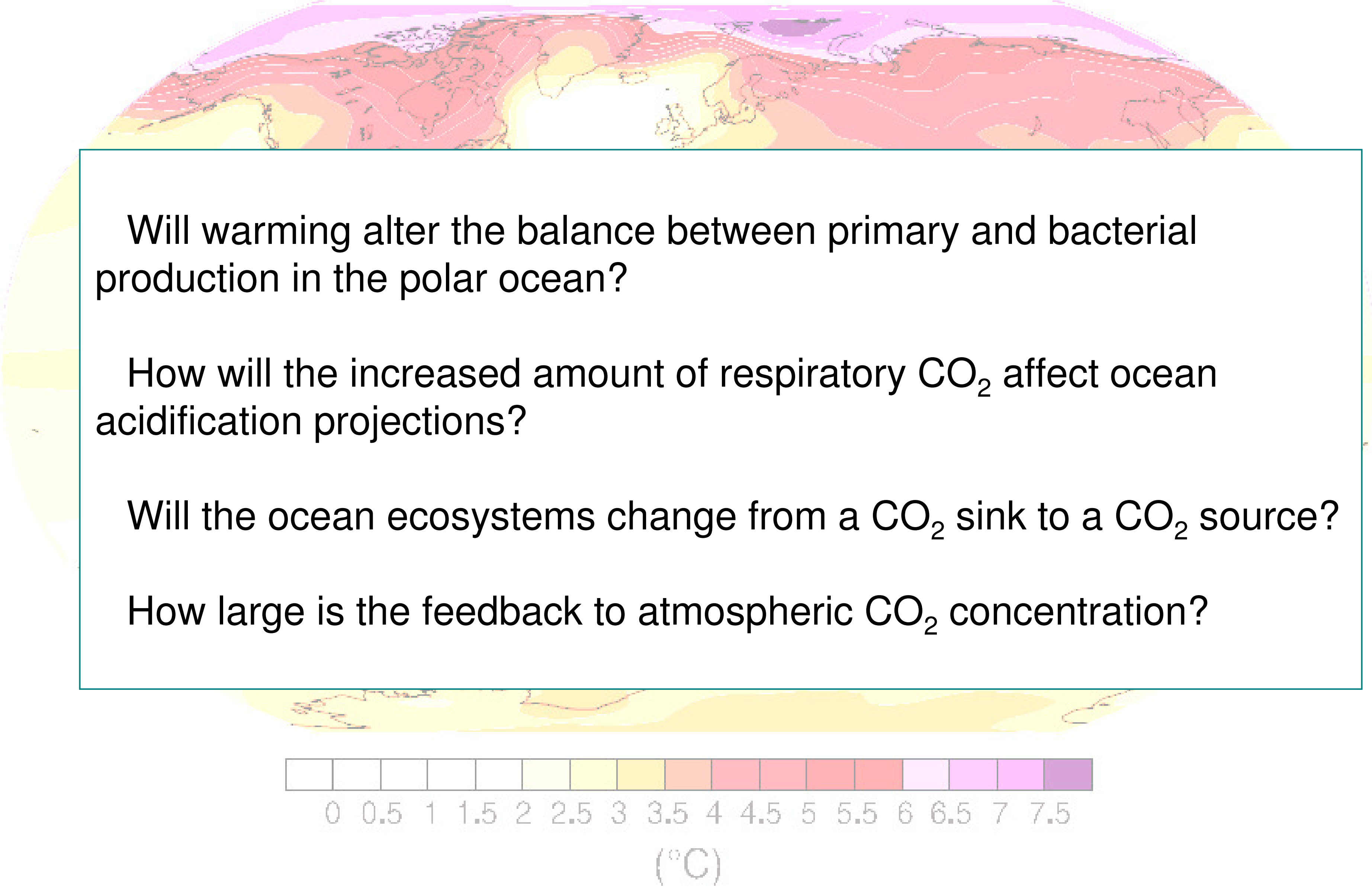


TEMPERATURE EFFECTS ON A GLOBAL SCALE



Laws et al. 2000

WHAT DO WE NEED TO KNOW BETTER?

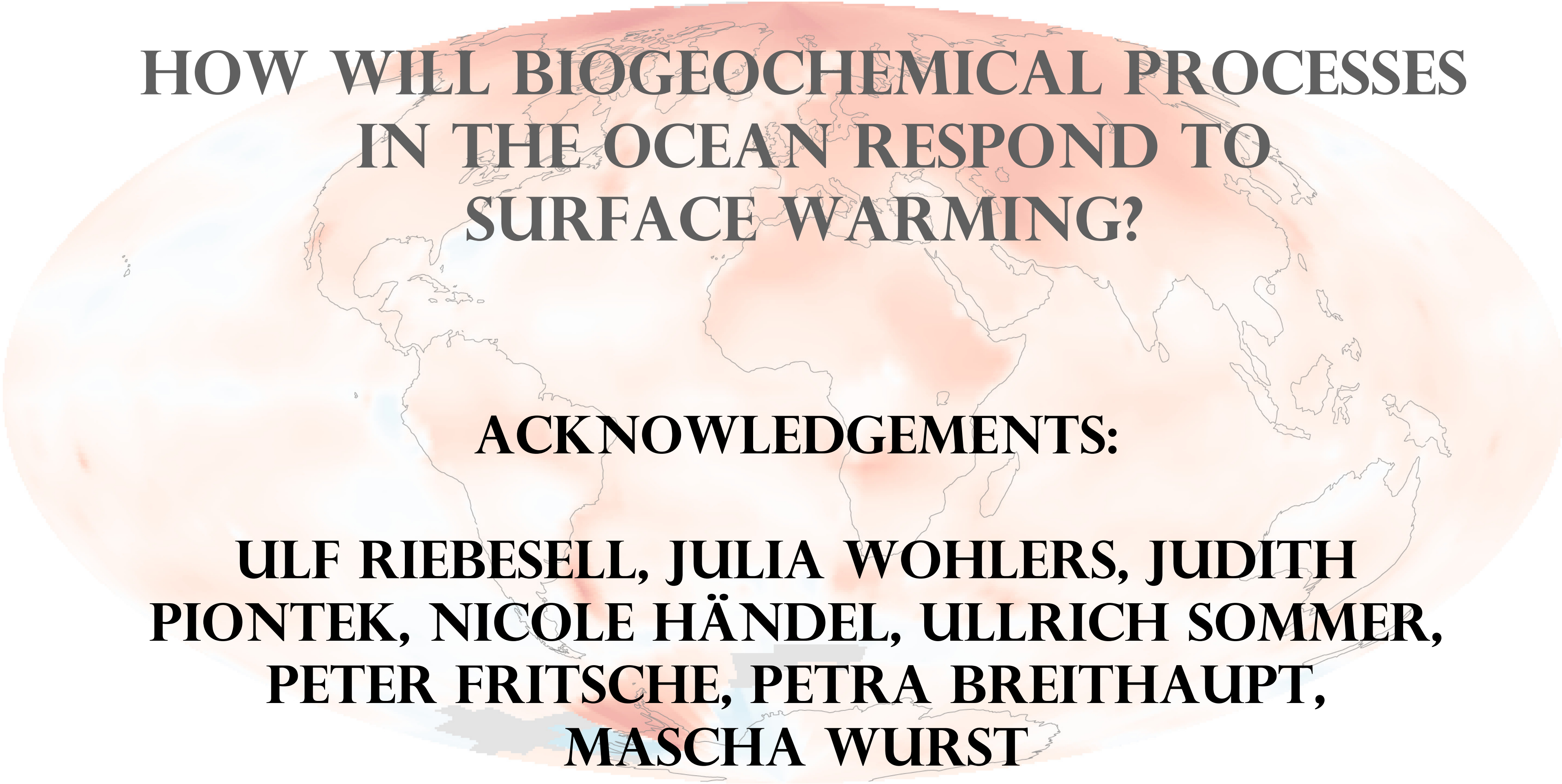


Will warming alter the balance between primary and bacterial production in the polar ocean?

How will the increased amount of respiratory CO_2 affect ocean acidification projections?

Will the ocean ecosystems change from a CO_2 sink to a CO_2 source?

How large is the feedback to atmospheric CO_2 concentration?



How will biogeochemical processes in the ocean respond to surface warming?

Acknowledgements:

Ulf Riebesell, Julia Wohlers, Judith Piontek, Nicole Händel, Ullrich Sommer, Peter Fritsche, Petra Breithaupt, Mascha Wurst

AWI